A Suite of Modelling Tools for Developing Cyber-Physical Systems and Digital Twins Implementations

Andrei Chiș
Business Informatics Research Center,
Faculty of Economics and Business Administration, Babeș-Bolyai University
Cluj-Napoca, Romania *andrei.chis@stud.ubbcluj.ro*

Ana-Maria Ghiran
Business Informatics Research Center,
Faculty of Economics and Business Administration, Babeș-Bolyai University
Cluj-Napoca, Romania *ana.ghiran@ubbcluj.ro*

Abstract

This paper reports on the integration between IoT and business process management, in order to help organisations implement Digital Twins more easily, thus achieving new levels of agility and developing higher quality data streams. The work was mapped on the Digital Engineer framework, highlighting the contributions made towards bridging the gap between process design in digital environments and process enactment in the real world. Moreover, we are also describing some research directions that would lead to a stronger coupling between digital and physical environments, leveraging the benefits of conceptual modelling.

Keywords: IoT, BPM, Digital Twins, Conceptual Modelling

1. Introduction

Modern day industrial enterprises aim to constantly increase the agility of their business processes, thus gaining a competitive advantage in their respective markets. In order to achieve this goal, such companies are looking to integrate Internet of Things (IoT) capabilities into their industrial resources, alongside employing business processes diagrams expressed with standards like BPMN [1].

Our work proposes a series of modelling tools as demonstrators on the feasibility of a solution that bridges the gap between IoT and process modelling in industrial settings. By working in this direction, we lay the ground for Digital Twins support, connecting the design time and the execution time of business processes.

Our efforts are oriented towards extending the open source implementation of BPMN standard, available in Bee-Up modelling environment [2]. The extensions are done on syntax, semantics, notation but also functional levels, in order to achieve the desired integration between design time and run time of business processes.

This paper formulates a position with respect to how business process diagrams can be linked with IoT capabilities motivated by the compelling value provided by having the modelling tool both as a representation medium for business assets and as a controlling environment for them.

We have achieved some promising results [3] with regard to the integration of IoT in modern day enterprises, but accomplishing our goal in combining these two apparently disjoint fields, requires developing more examples of modelling tools or extending the previous ones (e.g. by adding more diverse communication protocols, thus enriching support for a larger variety of smart devices).

The next major milestone on our research roadmap is the integration of robots with our modelling tools.

The rest of the paper is structured as follows: section 2 discusses the main characteristics that position our work in the Digital Engineer framework [4], while section 3 provides a survey of some of the most relevant related works. Section 4 describes the main goals that we plan to achieve in the future. The paper ends with conclusions.

2. Innovating in the Digital Engineer Framework

As a guide in achieving our research and development goals, we apply the principles described in [4]. Figure 1 consists of an instantiation of the elements that compose a smart innovation environment, mapped to our work.

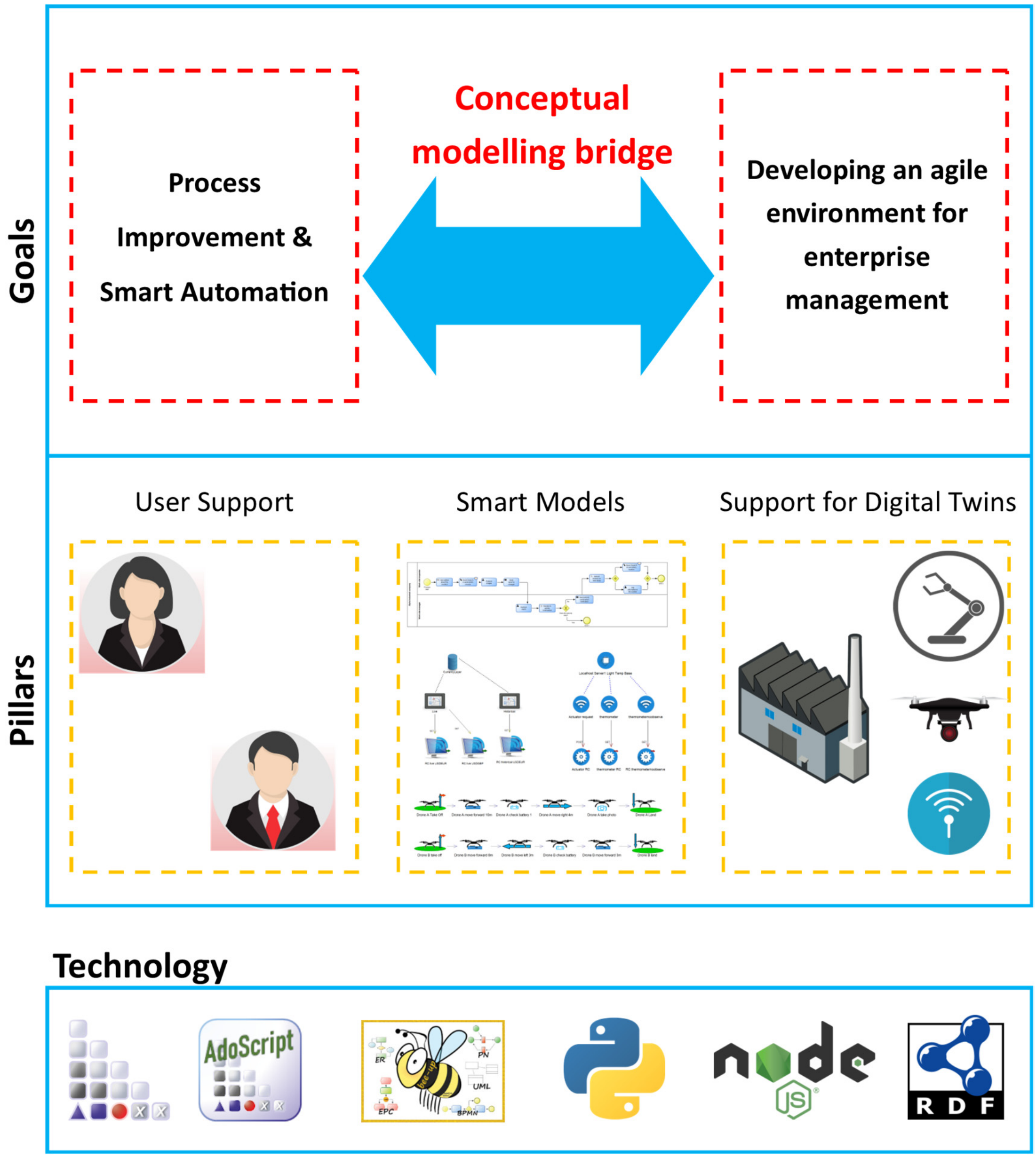

Fig. 1. Instantiating the elements that compose our work

The upper side of figure 1 displays the main goals we follow when doing our research. Our work provides an interoperability layer between several communication protocols which can be used in many Industry 4.0 applications. We are able to orchestrate the integration of heterogeneous data retrieval and smart device control using a suite of modelling tools [3] that we developed in the fully fledge metamodeling platform ADOxx [5].

The main pillars that provide the foreground of our work consist of developing domain specific modelling tools that can be easily used by both technical and non-technical stakeholders in different organizations. Subsequently, these are used to create smart models that employ model-driven process execution functionalities and support the implementation of Digital Twins.

On the technology side, we harnessed ADOxx' [5] capabilities in developing modelling tools in an agile and iterative way, using the principles of Agile Modelling Method Engineering (AMME) as initially introduced by Karagiannis [6]. AdoScript [7] is the main scripting language, accompanied by Node.js and Python for external functionalities. We can also export the created models in RDF [8] format, storing them as graphs on dedicated servers, which greatly improves querying capabilities.

We decided to position our work in the Digital Engineer framework because it also serves in simulating organizational flows, allowing stakeholders to take the best process design decisions, before implementation. This facet highlights one of the main characteristics of Digital Engineers – the ability to use the latest digital technologies in order to achieve major process improvements [4]. Our developed modelling tools enable a digital environment where the modern Digital Engineer has the ability to assess de quality of data flows and process execution before the roll out phase.

In the following, we will present two of our main achievements: the first one is a modelling tool that allows interoperability between IoT protocols and business process management, providing support for integrating API data requests in modern day processes. The second one, is a work in progress, that aims to bridge the gap between drone fleet management and business process modelling, laying the foundation for broader smart device integration in the future.

2.1. Heterogeneous Data Orchestration

Our previous work [3] presented a modelling tool that was created with the scope of facilitating data orchestration in various environments. We provided support for HTTP and CoAP [9] protocols, bridging in this way the gap between IoT and industrial process management with the help of conceptual modelling. We implemented a series of new concepts alongside the existing BPMN ones, which allow users to send API requests to both HTTP and CoAP endpoints. As CoAP is one of the main protocols used in the IoT space, it also allows the control of different devices. More specifically, we are able to send data retrieving queries or actuator controlling requests, directly from the modelling environment.

Another functionality that we implemented in this tool pertains to the automation of a series of endpoint requests, according to a predefined order defined in a BPMN diagram. We have developed an inter-model algorithm that parses the BPMN process model and after that, with the help of semantic links between the process model and the API requests' models, performs the data retrieval process.

2.2. Smart Device Control & Digital Twin Support

Furthermore, we have another work in progress regarding the combination of IoT with business processes. It employs a conceptual modelling layer between modern day business processes and drone fleet management. In this case, we added some modelling concepts and functionalities that allow commanding drone flight missions directly from the modelling environment, leveraged by the UDP protocol.

Other important aspects that were treated in this modelling tool are regarding the implementation of roundtrip engineering capabilities and adding support for generating process models from written text with the help of NLP (Natural Language Processing). These functionalities support the implementation of Digital Twins as the reverse engineering part ensures a transition from the digital ecosystem to the real world and vice versa. More specifically, we are able to generate machine readable code from a process diagram but also to generate diagrams from a human language text (due to NLP). In this way we ensured the highest level of coupling between design time and run time, allowing bidirectional propagation of changes.

In case of NLP, actions related to the movement type of the drones, direction or distances that need to be covered, written in textual form by the user in the modelling tool, are recognized by the algorithm and transformed into their related concepts in the modelling environment. This feature can be particularly helpful for users that have less experience in working with modelling tools, leading to an increased probability for adoption of our artefact.

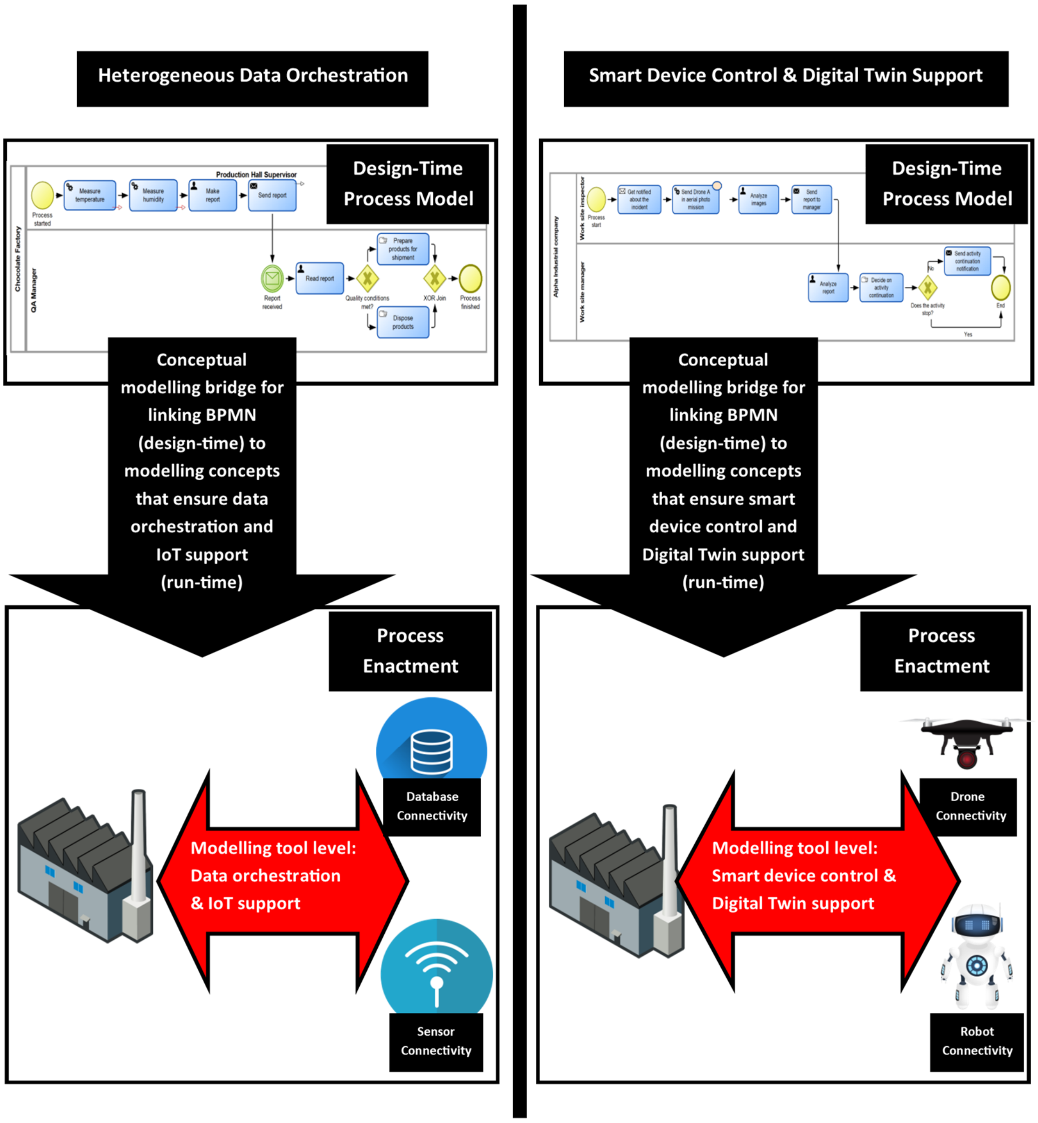

Fig. 2. Contribution Overview

Figure 2 displays the contribution overview for both our proposed modelling tools, containing samples of BPMN processes in the upper part in both cases (it does not matter to identify the exact name of the activities from the process diagrams, but rather that they can dictate the flow of execution). On the left we displayed the main points from the BPMN extension for heterogeneous data orchestration, thoroughly detailed in [3]. On the right side, we displayed in a similar fashion the main contribution of our work in progress that aims to provide smart device control integration with process management and support for Digital Twins' implementation. Even though our research maintains a primary direction in integrating business process management and IoT artefacts, we aim to differentiate our developed modelling tools in regards to the used protocols and connected artefacts. This can be seen in the lower part of figure 2, where the modelling tool from the left side is more oriented towards sensors and data endpoints, while the one on the right aims to provide connectivity to smart devices.

3. Related Works

The advances in the area of integrating IoT and business process management have been well represented during the last years. This topic continues to be of great interest to both academics and private organizations, fact that is visible in the multitude of published papers and organized conferences in this area.

The work done in [10] highlights the major benefits that arise as IoT sensor data is coupled with business processes – e.g. automatic discovery of process events. It also describes the framework that needs to be followed when developing the IoT architecture. The article suggests a series of principles that need to be followed when melding IoT and BPM, such as placing sensors in a process aware way or concretizing abstract process models.

With regard to this set of principles, we apply them in joining IoT and BPM, having the open source implementation of BPMN standard from the Bee-Up tool as our starting point.

Graja et al. [11] worked on developing BPMN4CPS, also an extension to the BPMN standard that can be used in order to model cyber-physical systems. Their case study is oriented towards a system of ambulance drones, which relates to the work we have in progress right now, in which we define a BPMN extension for drone control.

Moreover, a series of workshops such as BP-Meet-IoT [12] have emerged over the course of last years, aiming to bring together academics and industry leaders to discuss the possible approaches in which business process management can be linked with IoT sensors, towards more IoT-aware business operations.

4. Future Works

For our future research we aim to continue our work in the direction of automating business processes and enabling stronger couplings between process models and real world contexts, leading to a broader adoption of Digital Twins.

In order to do this, we want to expand RPA (Robotic Process Automation) [13] from automating office tasks to more industrial use cases that deal with the convergence between IoT and process modelling. Moreover, we plan to integrate more smart devices in our modelling tools, continuing the direction started with the integration of drones. One of our main future projects is adding conceptual modelling support for NAO Robots [14], later on expanding to factory and industrial robots. This direction can also be accomplished by adding more protocol integrations to the work done in [3].

5. Conclusions

Our research is directed towards bridging the gap between IoT and modern day business process management, helping companies acquire new levels of agility and efficiency in their operations. We developed a suite of modelling tools that allow the simulation of cyber-physical systems, aiming to help Digital Engineers seamlessly integrate IoT artefacts in diverse business scenarios.

The usage of our modelling tools would help companies in better mapping their Industry 4.0 business activities, gaining more agility in their operations, thanks to the bridging between the design-time phase and the run-time phase of processes. Companies would be able to deploy Digital Twins more easily, which ensures better management of operations and increased efficiency in resource allocation. This comes as an important helper in the process of providing better returns and increased added value to all the relevant stakeholders.

We want to continue our work developing new modelling tools that will be able to support more communication protocols and with a series of new functionalities supported by technologies such as NLP, in close correlation with our research goals resulting in a larger adoption of Digital Twins in various sectors.

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